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ABSTRACT

A study of the communication skill needs of the foreign teaching associate (TA) in American universities focused on two questions: (1) What does a foreign TA do to communicate information in an American classroom in terms of comunication strategies and devices for cohesion and coherence of discourse? and (2) How does this compare with the way an American TA communicates information and uses these devices? The subjects were a Korean TA and an American TA in astronomy, both Ph.D. candidates at the University of Minnesota. The Korean student had never before been in an English-speaking country, and had not concentrated on learning aural-oral skills in English. Both were teaching an undergraduate astronomy course. A lecture by each TA was audiotaped and notes taken simultaneously on the blackboard use, gestures, and eye contact of the TAs. The tapes were analyzed, and a transcript of the Korean TA's lecture was discussed with him to learn of his intentions in parts of the discourse. Based on the discourse analysis, it is suggested that courses designed to help TAs communicate effectively in the American university classroom focus on practicing flexibility in the linguistic domain and on effective communication strategies. This way, TAs can express the importance of a point, how two ideas relate, or how an equation can be applied to a problem. Transcripts of the two subjects' lectures are appended. (MSE)

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Lecture Discourse of a Foreign TA: A Preliminary Needs Assessment

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1.0 Introduction

To date, lecture discourse in English for Special Purposes (ESP) has been examined from the point of view of what the native speaker does and how the foreign student understands or does not understand that communication. With the increasing number of foreign Teaching Associates (TAs) giving lectures in American universities, and with a concomitant decreasing tolerance of foreigners on the part of American students, it is important to examine lecture discourse from another perspective--the communication of the foreign TA.

Relevant to this perspective is the work on communication strategies (Varadi 1973; Tarone 1977, 1979; Galvan and Campbell 1978), cohesion (Halliday and Hasan 1976), and coherence (Sinclair and Coulthard 1975; Cook 1975; Candlin 1978).

Although work on communication strategies has not yet been related to lecture discourse, I believe much of it is applicable. Tarone (1979) has defined communication strategy in terms of one-to-one discourse, as "a mutual attempt of two interlocutors to agree on a meaning in situations where requisite meaning structures do not seem to be shared." To the extent that lecturers communicate as if they were in one-to-one situations, the notion of communication strategies can be applied to lecture discourse. The necessary criteria for use of a communication strategy are three-fold:

1) a speaker desires to communicate a meaning x to a listener;
2) the speaker believes the linguistic or sociolinguistic structure desired to communicate meaning x is unavailable, or is not shared with the listener;
3) the speaker chooses to:
   a) avoid--not attempt to communicate meaning x; or,
   b) attempt alternate means to communicate meaning x.
   The speaker stops trying alternatives when it seems clear to the speaker that there is shared meaning (Tarone 1979).

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The primary questions of this study are, then, 1) what does a foreign TA do to communicate information in an American classroom in terms of communication strategies and devices for cohesion and coherence of discourse? and 2) how does this compare to the way an American TA communicates information and uses these devices? This paper begins to answer these questions by describing a case study of one foreign TA's lecture discourse. It is hoped that the results will eventually aid him in developing his language and teaching ability in the U.S. system and lead to further investigation of lecture discourse and communication strategies of other foreign TAs.

2.0 Subjects

A Korean, who will be called Kim, and an American, who will be referred to as Joe, were both Ph.D. candidates in astronomy at the University of Minnesota. Kim arrived in the U.S. one week before the beginning of Fall quarter. He received his Master of Science in Korea and taught for three years in his country. Although he had read a good deal of astronomy in English and had written journal articles in English, he had never been in an English-speaking country, nor had he ever concentrated on aural-oral skills in English. At the time of the study, both Kim and Joe were TAs for an undergraduate astronomy course. Joe had been a TA for the course before with the same text.

3.0 Procedure

Two lectures on the same area of astronomy, one given by Kim and the other by Joe, were audiotaped. In this department, and for this introductory course, the TAs are told a week ahead what chapter from the lab manual to cover in the lab session. They individually select the important points to stress and how to present the material. In this case, Kim gave his students a sheet of notes which followed the manual's order, and his own lecture, he said, also followed this order. Joe, however, did not follow this order, nor did he give out any notes. Each TA had forty-five minutes for lecture, another forty-five to help students with the problems in the manual, and then forty-five to assist students in observing stars through the telescope.

During the lectures I made a written account, syncronized with the numbers on the tape, of the TA's use of the blackboard, gestures and eye contact. This is, of course, not as accurate as a videotape would be, but Kim expressed embarrassment and intimidation at my presence[1], so it seemed that a camera would further inhibit him. The lectures were recorded on the same evening in the sixth week of the quarter.

In the lecture situation, criterion (1) is present. The primary motivation of an instructor is usually to communicate knowledge or understanding of the material. When a foreigner is the instructor, criterion (2) could arise frequently. It can be shown that, when criteria (1) and (2) exist for a foreign TA, s/he does in fact either choose to avoid (3a) or to use various communication strategies to get the point across (3b).

Central to the definition of communication strategies is the interaction wherein the speaker and listener agree on a meaning where one is not shared. In one-to-one situations this may be accomplished more easily than in lecture situations where the speaker is physically distant from his/her audience and the individuals in the audience may not all participate--verbally or non-verbally--in negotiating for meaning. However, Candlin (1978) mentions that lectures have an interactive nature and states that "few lecturers can be so insensitive as to be unaware of all of the reactions of their hearers." However, when the speakers and listeners are of different cultures, the reactions of the audience may not be interpretable by the lecturer. Whatever interaction does exist, it involves the coherence of the lecture where coherence is defined as "the communicative use to which utterances are put in the performance of social action" (Cook in Candlin, 1978:15). Some of the utterances may be part of the TA's attempt to interact with the listeners and to negotiate meanings. Others may be marking an alternative expression or perhaps even the avoidance of a concept. For a text to have coherence, the sequence of concepts or facts has to follow from the preceding utterances. The semantic relationships have to be implicitly clear or be made explicit. A problem would occur if a TA chooses to avoid the connecting idea because of his/her limited linguistic system and has no alternative means of expressing the relationship. In this case, the strategy of avoidance weakens the lecture's coherence. It appears, then, that there is an interdependence between communication strategies and coherence: the latter marking the existence of the former, but also the former possibly eliminating the latter.

An interdependence of a different sort would seem to exist between communication strategies and cohesion. The strategy the speaker chooses will affect which of the cohesive devices (repetition, substitution, lexical cohesion, ellipsis) can be used. For instance, an approximation to a difficult noun phrase my be to substitute with a pronoun. This may not express the speaker's exact meaning, but it can be an alternative.

The lectures were transcribed with attention paid to intonation, stress, and pause length. I reviewed the transcription of Kim's lecture with him. In this review session, I tried to elicit from him some of his intentions in certain parts of the discourse. Kim initiated a discussion on the Korean lecturing style and his own frustrations with English in the classroom situation.

4.0 Data

The two TAs' discussions of two concepts--trigonometric parallax and spectroscopic parallax--were examined in depth. For some observations, however, examples from other parts of the lectures were used. The two concepts took only twelve minutes in Joe's lecture, while they were intertwined in thirty-five minutes of Kim's lecture.

4.1 Non-verbal Communication

The most obvious difference between the two lecturers was in their use of non-verbal communication, especially the use of the blackboard and gestures. Kim's use of the blackboard was extensive, while Joe's was camparatively limited. At the same time, Joe's use of gestures was extensive and Kim's was very limited.

Whenever Kim used a specialized term he repeated the term a number of times and wrote it on the board. This seemed to occur whether or not the word was new to the students. In the following example, the word spectrum was crucial to the main point of the discussion, but also was a familiar concept to the students at this point. Kim said:

> a) last week last week we studied spectrum of the star [ke] O star B star A star [ke] (writes the other letters) spectral type [ke] eh spectrum is eh spectrum (writes) (lines 34-36, Appendix A)

In the next example, trigonometric parallax is used for the first time.

> b) this parallax is called trogonometric parallax (writes) trigonometric parallax (lines 115-116, Appendix A)

There are other examples wherein Kim writes a word, e.g., flux, or a phrase, e.g., the closest star from the O (line 56, Appendix A), but doesn't tie these visually into any other part of his diagrams. While lecturing, Kim remained at the board facing sideways and looking at the board. He rarely made eye contact with his listeners and often had his back to the class.

Joe used the board only for equations and diagrams and not for new terms, and he was almost always facing the students. When he wrote on the board he did turn away from them, but when he explained what he had written he stepped to the side and faced them again.

Kim rarely used gestural illustrations, while Joe, in contrast, used them frequently. Kim's only gesture was once when he said an angle was tiny, he indicated smallness with his finger and thumb close together. Joe's uses involved much broader gestures. For instance, he used an example of a finger in front of his face to demonstrate trigonometric parallax. Throughout his description he had his finger moving back and forth in front of his face, while his eyes were opening and shutting tightly, contorting his face. This example gave a scientific name to a common event and thus made scientific knowledge more accessible to the layperson.

4.2 Cohesion

Kim's use of the board related specifically to his use of language, and, in particular, his use of cohesion. Candlin, following Halliday and Hasan, has described five devices which give a text cohesion: reference, substitution, lexical cohesion, ellipsis, and conjunction. Of these, the first three were the most important in Kim's lecture.

4.2.1 Reference and Substitution

The division of reference into exophoric--reference to the context--and endophoric--reference to items within the text--is useful in this description.

Kim used exophoric this or here when he pointed to a variable in an equation or a portion of a diagram that he had drawn on the board. For example, as he said line 39 (Appendix A), he pointed to the equation he had just written. Joe also used this and here in the same context (e.g., "this angle here" line 32, Appendix B). About fifty percent of Kim's uses of this were in conjunction with one (e.g., lines 69-70 Appendix A), another twenty-five percent were with part, which was usually an elliptical form(e.g., "this part star and this part (of the star) we compare..."). In the remaining cases, he used a noun (this spectral type, this diagram). Joe, when he used exophoric this, always used the noun (e.g., this angle, this equation).

Besides these examples of exophoric reference, Kim did not use any other cohesive devices. He used only the definite article (Korean doesn't have an indefinite article),

so he didn't make use of the full English referential system of articles. He also did not use any pronouns or other types of substitution except those mentioned above and one token example of same.

4.2.2 Lexical Cohesion

Several options are available to establish cohesion through lexical items. These include the use of synonyms, hyponyms, a common noun (after a proper one has been used), superordination, and repetition. Of these, Kim used the latter extensively and very little else. Repetition was also the most common type of lexical cohesion Joe used. Examples of cohesion through repetition in Kim's data are:

c) star is here and sun, earth goes around the sun in one point one... (lines 46-47, Appendix A)

d) massive star has luminosity has high luminosity because eh because massive star has has has fuel...(lines 88-89, Appendix A)

In sentences c) and d), the repetition of the nouns sun and massive star link one part of the sentence with another part. In c) Kim was drawing and describing a diagram with his back to the students. In d) the use of the same noun rather than a pronoun is cohesive.

In Joe's data there were also numerous examples of repetition but very few other forms of lexical cohesion. There were contexts where substitution or ellipsis might be expected, but where Joe used repetition instead. Two instances of his use of repetition are:

e) to find the distance the distance is just equal to one over parallax [ke] and that will give you a distance in parsecs that's the first way to determine the distance of the stars...(lines 42-46, Appendix B)

f) the problem with dust can be accounted for if you know how much dust is along your line of sight you can calculate the resonating effect of the dust (lines 154-157, Appendix B)

In e) and f) Joe could have used synonyms for distance and dust, or he could have used pronouns or an elliptical form.

Other examples of Kim's use of repetition seemed to function for emphasis or narration, as seen in 4.1, and were not part of lexical cohesion. For instance, a term repeated for narration of the diagram was:

g) but eh distance star is not move, distance star, distance star (line 51, Appendix A)

The repetition of an entire sentence also occurred. This

may have been used for emphasis, such as in the following:

h) Luminosity is different. Luminosity is different. (line 22, Appendix A)

Repetition used for emphasis only or narration did not occur in Joe's data. Joe repeated a concept by restating it in several ways before he moved on to another point. He did this in lines 111-151 (Appendix B) to explain the dimness of a star behind a dust cloud. He said:

i) it (dust) tends to block starlight...stars behind dust clouds appear dimmer and redder to us...light is scattered by dust...starlight is redder through dust clouds it's also dimmer through dust clouds...a lot of it is just absorbed by the dust...if we're looking at a star behind a dust cloud it will appear dimmer...

4.3 Coherence

The overall structure and coherence of Kim's lecture was dependent on following the notes he wrote and distributed before the class, and the manual's explanation. He began his lecture by saying "open your book page 99" and then instructed students to read this chapter at home. Though he never directed students' attention to the notes he gave them, he did read a sentence from them at one point. The students did not appear to be referring to the notes during his lecture. At one point, Kim wrote 1) and 2) on the board, but he didn't make any statement about how the two points were related, e.g., if 2) followed from 1), or if they were equally important, or if they were both sub-points of some other aspect. On the notes, however, the two points were given again, under the heading "Basic Stellar Observations."

In another instance, neither Kim's lecture nor his notes made a relationship explicit. In lines 68-85 (Appendix A), he explained what the bolometric magnitude is. He diagramed and mentioned the regions of the spectrum and said that the visual region was the absolute magnitude, but that it was only part. He said, "so whole region magnitude and bolometric magnitude." (line 80) by which he seemed to mean the magnitude of the whole region is the bolometric magnitude. Before he went into this explanation he mentioned luminosity and after he finished he mentioned solar mass and luminosity. If these were connected, he did not say so. His notes, however, showed that there was a connection. He wrote,

Distance ← luminosity ← γ ray
x-ray
ultraviolet
visible radiation
infrared
radio

∴ we need a bolometric correction (BC)

$M_{bol} = M_v - BC$ where M_{bol} bolometric magnitude

Although distance and luminosity are now related to the bolometric correction and the bolometric magnitude, it is still not explicitly stated why we need a bolometric correction. It is only from reading the manual that all of these connections are explicitly made clear.

Joe's lecture had a different overall structure, and it followed neither the manual nor any prepared notes. His structure was revealed through his use of markers. Markers are words or phrases which function as glosses to speech acts such as eliciting, accepting, informing, commenting, or concluding. They also serve to gloss a meta-statement or an aside. Joe used many such metastatements to refer to the structure of the lecture. These included, "one is trigonometric parallax and the other is spectroscopic parallax," "one of the facts is," "there are two limitations on it," "for a couple of reasons," etc. He also used markers to summarize or conclude points. He said, for example, "So that's the first way to determine the distance of the stars," "the point is...," "That's the non-scientific reason why you have two different H-R diagrams." He used alright, now, ok, remember, and well as markers and/or starters of points he made. When he digressed, he then refocused by saying "But that's really off the point, the point is..." He also used asides. For example, he said, "I'll try to keep talking while I roll up my sleeve," and "this is going to happen all next quarter, my friends are in the lab smiling at me when I talk."

While there were numerous examples of different markers in Joe's data, what appeared in Kim's speech was the overgeneralized use of only one marker. He used ok as [ke] or [oke] (with several intonation patterns) excessively to mark many different speech acts. This marker also occurred in Joe's lecture but there were only ten instances of it in the data in Appendix B. Nine of these were with level intonation, and occurred after he had finished writing an equation or variable on the board or after he referred to an equation. The tenth instance had rising-falling intonation [oke] and occurred after he had finished a long digression and before he got back to his original line of discussion (line 164, Appendix B).

Kim's [ke] with level intonation occurred with or without references to something written on the board, as in the following:

j) this spectral type related to temperature of star (writes) [ke] so spectral type is O B A F G K (student adds: M) M (writes) [ke] luminosity eh high luminosity low luminosity [ke] (lines 7-9, Appendix A)

The most frequent marker in Kim's lecture was [ke] with rising intonation. An example of this is in lines 52-55, Appendix A.

Another way which Kim frequently used ok was as a double ok with rising and then rising-falling intonation [oke oke]. These appear after a point was made and before beginning another. The following are examples of this double function:

k) this one is bolometric magnitude [ke oke] so solar mass H-R diagram...(lines 84-86, Appendix A)

l) this star is sun [oke oke] this spectroscopic parallax we can calculate distance star...(lines 151-153, Appendix A)

One last intonation pattern Kim used with ok was similar to the intonation just mentioned but lower--[oke]. This one occurred before Kim repeated an idea or tried to explain it in another way. He said:

m) this star has size eh big size but not massive this um [oke] although this star has size big size eh eh not not massive (lines 105-106, Appendix A)

Another example of this same intonation pattern on ok is the following:

n) distance is eh, how to study distance eh [oke] star is here, and sun, earth goes around the sun...(lines 45-47, Appendix A)

Other than ok, there are very few words or phrases which functioned as markers of acts in Kim's lecture. He did use a rhetorical question (line 72, Appendix A). He also sequenced two points he made with a type of metastatement in lines 128 and 139, Appendix A. This was clearer on the board than it was verbally.

5.0 Discussion

The difference in Joe's and Kim's classroom communication is not simply a difference in quantity, although this is a factor (Appendix B is only the first third of Joe's lecture,

while Appendix A is Kim's entire lecture). It is also a difference in kind. In terms of communication strategies, it appears that Kim uses avoidance of explanations as well as approximation to these. When the alternative expression does not lend itself to the meaning, then the communication is avoided or abandoned. This results in Kim presenting a bare outline of the information without the sorts of background and extran information that Joe gives.

An example of this avoidance is in Kim's particular use of ok. When we discussed conclusions, he said he wanted to do more than say "This one is very important" (line 158, Appendix A), but he didn't have enough English to explain more. His ideas couldn't be expressed at all by the language he has and the one comment made neither approximates all he had to say nor indicates an abandonment of the message. He simply avoids the discussion.

Kim's ok with rising intonation represents the communication strategy of approximation. He said he wanted to ask a question of the students to find out if they understood, but didn't know how to ask it. The [ke] marks his alternative means of communicating that meaning, or approximating the meaning.

In other places, such as sentences o) and p) below, [ke] seems to be an indicator of message abandonment.

o) but eh distant star is not move. distant star, distant star but six months, eh, earth is here [ke] (elicitation) so take photometer of star is this star is [ke] (message abandonment) because this one is [ke] (message abandonment) this this one is so sun...(lines 52-55, Appendix A)

p) we observe m-v eh with photometer photometer and H-R H-R observe [ke] (message abandonment) d is eh ah distance (lines 43-45, Appendix A)

In these instances, not enough information has been gained from the text or from his drawing to let the listener know what has been left out. It may be that Kim doesn't have the words he needs to describe the situation and so leaves off in the middle of a sentence or idea.

The last use of ok mentioned in 4.3, [oke] , is not itself an approximation or abandonment. Rather, in m) it marks Kim's realization that what he had just said was an inadequate approximation and that he had decided on an alternative way in which to express the idea more clearly. In n) he doesn't abandon or avoid the message but decides on an alternative way to explain it and does resort to a drawing.

Kim's extensive use of the blackboard throughout this lecture is also a communication strategy--mime--insofar as he uses it to communicate his intended meaning (as in n)). Kim ensures that his listeners will understand a key word or phrase when he writes it on the board (a) and b)) as he may doubt his own pronunciation. Joe, in contrast, never used the board for this purpose. In discussions I've had with Kim, he has tried to explain a concept verbally, but always resorts to drawing a diagram on paper or writing various words out. His drawings are very precise and neat, so he probably feels more secure with this means of communication.

Kim's use of the blackboard, thus, is an example of an alternate means to communicate (mime). The reason that this can be analyzed as an alternative means of communication and not simply as a supplement to his lecture is because of the many times he writes on the board without saying anything (a)) or saying something in such a low voice that it is inaudible. This also seems to be the case with Kim's notes. They serve as an alternative (again, written) to verbal communication.

The reason for Kim's comparative lack of gestural examples may be a cultural constraint he feels. The gesture Joe uses to visually describe the trigonometric parallax example is a visual explanation Kim could use. However, Kim maintains that Korean lectures are formal and body language is limited and "stiff." Broad gestures such as Joe used might therefore be too informal for Kim to feel comfortable using. By relying only on written communication, and by not using gestural illustrations such as those Joe uses, Kim reduces the redundancy of his lecture's propositional content and limits informal interaction with his students.

A consequence of Kim's extensive use of the board and also possibly another consequence of culture, is his lack of eye contact with his students. This may also limit the interactive nature of his lecture and contribute to a formal tone.

In terms of cohesion, there is a difference in Joe's and Kim's use of exophoric reference such that Kim's use is more extensive. The combined use of the exophoric <u>this</u> and <u>one</u> or <u>part</u> as substituted or elliptical forms, respectively, functions as cohesive devices for Kim. It is not surprising that exophoric references occur frequently in these data. In fact, Halliday and Hasan, as Candlin points out, comment that exophoric reference is common in lectures. Why it is so much more common in Kim's lecture than in Joe's may be attributable to a communication strategy. Kim may be avoiding a word if he is not sure of his pronunciation, such as

variable in line 69 (Appendix A), as v, r, and l are all difficult for him. At other times he may be unsure of the grammatical construction of a sentence and can avoid it with the use of exophoric reference (line 64, Appendix A). In other cases, it seems that he is using one or part because he cannot think of another word (line 74, Appendix A). Thus it may be that the frequent use of exophoric this in conjunction with the substitution one or part are a cohesive device for Kim, but they also work to either help him avoid difficult pronunciation or sentence structures, or serve as an alternative means of saying something for which he doesn't have the vocabulary, that is, an example of approximation.

There is a similarity in the lexical cohesion used by Kim and Joe. Both use repetition of lexical items rather that substitution with pronouns in most cases. This is exemplified by utterances c-f. Of the various options for lexical cohesion, repetition of the noun seems to be the most explicit and this may be why Joe and Kim use it instead of other forms. In some of Kim's data, repetition functions for emphasis or narration and is not part of lexical cohesion (g) and h)). This type of repetition does not occur in Joe's data, although he does repeat a concept, as was seen in i). It may be that, not having linguistic versatility, Kim cannot restate a fact in more than one way, and so repeats it exactly instead.

While cohesion is important to unify the discourse, coherence is important to ensure that the listeners can follow the arguments. Also, a cohesive text is not necessarily a coherent one. This may be especially true of spoken discourse, because of the time that elapses between first mention of an idea and second mention. This lapse may include a number of other ideas or comments that occur to the speaker. Furthermore, because of the absence of visual paragraphs, the speaker must be clear as to how the ideas relate to one another. Without coherence, spoken discourse can only be a string of words.

There is a difference in the kind of coherence Kim and Joe have in their lectures. Both of them frequently add a phrase or word which could be called a marker, but Kim's are limited mostly to ok, while Joe uses "the first thing," "there are two types," "I could care less," "which is important to remember," etc. The coherence of Joe's lecture depends on these phrases. Without the connecting prose to express explicit and implicit relationships, or even to direct attention to the notes, however, Kim's lecture is difficult to follow. His uses of ok do not facilitate

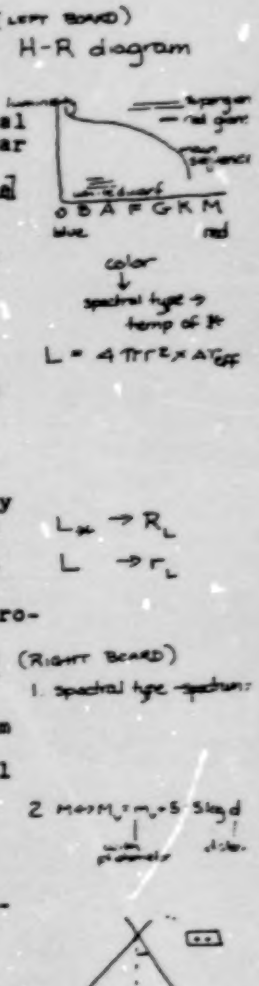
understanding. They are not sufficient to explain the use of an equation or how two facts are related. The coherence of Kim's lecture, however, is provided in the sheet of notes and the manual's explanation (as discussed in 4.3). As such, they are used as communication strategies, alternatives to the use of connecting prose. Kim also does not use the asides that Joe uses, which appear as a narrative of the speaker's thoughts and actions, and relate to him as a lecturer. They personalize the lecture and make it more informal.

6.0 Conclusion

This case study is a beginning in the examination of lecture discourse by non-native English speakers. It cannot be assumed that foreign TAs will want to adopt an informal attitude and interact with students more than they are used to doing or feel comfortable doing. However, courses which are designed to help TAs communicate effectively in the U.S. university classroom should focus on practicing flexibility in the linguistic domain and on effective communication strategies. The TAs should be able to express the importance of a point, how two ideas relate, or how an equation can be applied to a problem. In this way, the TA does not have to assimilate culturally, but is able to communicate successfully.

APPENDIX A: Transcription of the Korean's explanationof spectroscopic and trigonometric parallax and his simultaneous use of the blackboard

open your book page ninety-nine. today we study h-r diagram [ke] . you have to read this chapter in your home [oke oke] . h-r diagram, h-r diagram, and chapter one we know from the stars, eh color and luminosity, [ke] luminosity, these spectrum is blue color, these spectrum is red color, so color color related to spectral type [ke] this spectral type related to temperature of star [ke] so spectral type is O, B, A, F, G, K, (student: M) [ke] , luminosity. eh high luminosity, low luminosity [ke] so eh, so this part, eh this part is eh called main sequence stars this part white dwarf, white dwarf [ke] this part super giant, this part red giant [oke] because why we called giant, dwarf [oke oke] this part red giant this part white eh white dwarf and sun is sometimes white dwarf so because luminosity equals four pi r [skerd] [ke] stars area times [ke] effective temperature power [oke] so effective temperature, effective temperature the same [oke] so this part star and this part [ke] we compare this part star this part [ke] so same color related spectral type and related to temperature star so same temperature [ke] so effective temperature same, but luminosity is different luminosity is different. [ke] high luminosity and low luminosity so eh high luminosity is make high large, large large r and low luminosity eh small r so small r star is dwarf star [ke] (inaudible) another phenomenon luminosity relate eh towards another diagram luminosity relate to absolute magnitude and spectral color spectral type or temperature so eh spectroscope and spectral type supergiant main sequence white dwarf giant super giant [oke oke] eh in order we draw this diagram we know spectral type of star. spectral type of star and luminosity or absolute magnitude [ke oke] eh in order that we know spectral type we observe the spectrum of the star [ke] eh so last week last week we studied spectrum of the star [ke] C star B star A star [ke] spectral type [ke] eh spectrum is eh. spectrum of. if we know the pattern of absorption line we know about spectral type star [ke] absolute magnitude is m-v equals m-v plus five minus five log d with this equation is eh so this one is absolute magnitude [ke] this absolute magnitude is called correct magnitude this magnitude is visual magnitude so this eh is related to each other [oke] so m-v is is directly observation [ke] we observe m-v with photometer photometer and h-r h-r observe [ke] d is eh ah distance of star from us to star eh distance is eh. how to study distance eh [oke] star is here and sun, earth goes around the sun in one point one so and, one day earth is here [ke] so this time we observe the star [ke ke ke]



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[illegible] distance stars distance stars and we take the photo-
meter this star line like this this star, but eh distance
star is not move. distance star. distance star but six
months later, eh earth is here [ke] so take photometer of
star [ke] at this star is [ke] because this one is [ke] this
one is. at sun is here distance [ke ke] we measure paral-
lax this eh angle [ke] is [ke] eh is tiny very tiny but [oke]
so eh the closest star the star from sun is eh about.
four point five so pi the distance is, distance is one
over pi [ke] so unit is parsec. one parsec one parsec, [one
parsec] is distance that a star must be so that the dis-
tance from earth to sun appears to subtend exactly one
second, one second of one, remember one second of one
is subtend is one over one parsec but point five second
two parsec two seconds [ke] is two seconds [oke]. another
one if, eh distance of sun from us is. one parsec is
two point, one pars-- o no one second, one radiant one
radiant is, related to this two zero six two six five
second of one [ke] one parsec [ke] so [ke] but. this one is
[oke] eh we direct observe direct observation eh lumino-
sity this one and this one [ke] so we calculate we can
calculate absolute visual magnitude [ke] but this one is
absolute bolometric magnitude [ke] bolometric magnitude
is m so bolometric, what is bolometric magnitude, eh
as you know, solar, solar, in spectrum like this flux
and wavelength so, but, this part of this part is cool
region, this region is visual region [ke] so another is
ultraviolet region gamma ray region x-ray region in-
frared radio [ke] so we eh we eh use apparent telescope
we must we eh can eh visual region [ke] so this region
is absolute visual absolute magnitude but eh standard
radiation is whole radiation so eh we eh have a fraction
of [ke] so whole region whole region magnitude and bolo-
metric magnitude [ke] bolometric magnitude equals m-v
minus bolometric correction [ke] and in the case of dis-
tance star eh different bolometric magnitude. this one
minus this one is bolometric magnitude [ke oke] . so
solar mass is, h-r diagram O B. high luminosity low
luminosity [ke oke] solar mass eh massive eh massive star
and eh massive star massive star massive star has lumino-
sity has high luminosity because eh because massive star
has has has fuel burning fuel so a lot of h two hydrogen
[ke], massive star has eh a lot of burning fuel. eh, a lot
h two so massive star, eh are more luminous and so
massive star has short life short life short life time
of evolution short life time small small life short
life time and less massive star so less luminosity [ke]
so long life time [ke] so this part distant star is mass-
ive star [ke] massive star mass-ive star, low less mass
low luminosity [ke] what is difference, massive star or
less massive star (students: less massive, white dwarf)

the closest star from O

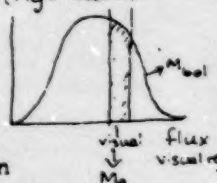
π =

$d = \frac{1}{\pi}$ (pc)

1 d = 1 pc
.5 d = 1 pc
2 d = 1 pc

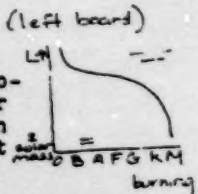
1 pc = 2.
1 rad = 206265
(erases left board)

(right board)



$M_{bol} = M_v - BC$

(left board)



burning fuel
a lot of H_2

M↑ L↑ ⇒T↓

M↓ L↓ ⇒T↑
massive

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massive star less massive star (student: high density) (laughter) yeah, high density high density eh. massive star white dwarf is about two solar mass [oke] eh so eh massive star is less density this star is more massive star or less massive star (student: less massive) this star has size eh big size but not massive [oke] although this star has eh has size big size eh eh not not massive always not massive so this um we prove this part of star is massive star this part is low massive star but this part of star is eh nobody know [ke ke oke] size big [ke] white dwarf is size small size but eh one hundred kiloparsecs white dwarf. small size small size but this one is eh eh big size from the sun to Jupiter [ke] Jupiter about three a-u [ke ke] about one a-u kilometer ten is ten equals four point five k-m small size [ke oke] eh. this one is an eh this parallax is called trigonometric parallax trigonometric parallax [ke] we but eh use this eh h-r diagram eh we define another parallax eh spectroscopic parallax, eh spectroscopic parallax (spectroscopic parallax is) spectroscopic parallax very important because, you go home why (student: have to) have to, trigonometric parallax we we trigonometric parallax we measure the near star [ke] because eh telescope resolution telescope resolution telescope resolution is about one point one five, spectrum of y so we cannot observe the angle less than one point one five [ke] so eh t equals one point one five [ke] so eh, distance more than one point one five parsecs cannot observe this distance so another method spectroscopy spe-tro-sco-py parallax [oke] spectroscope is so spectral type and eh this class spectral type and luminosity class luminosity class luminosity class means giant super giant super giant dwarf eh white dwarf so [oke] exam-- for example g two ke g two g two g two type and luminosity class main sequence [ke oke] so use this h-r diagram g two g two main sequence [ke ke] so we can we can know the absolute magnitude correct magnitude of this star one point seven [ke oke] so we know about one point seven [oke] another one two. and we eh observe eh apparent magnitude of this star [oke ke] apparent magnitude [ke] apparent magnitude about two point one minus six five [ke] we can compare apparent magnitude with distance of star [oke] so eh eh this one eh this one and this one so using this formula m-v equals m-v plus five minus five log d [ke] so using this equation determine distance of stars [ke] so m-v five o four point seven minus twenty point five over five minus five d log d o four point seven minus five minus five minus five minus two six point two divided by five minus log d so log d equals minus five point two four [ke] so d equals

1 = 10" x 4.5 km

(erase right board)

(right board)

near *

T = 1.15

∠ 1.15

d = 1/1.15 pc

spectroscope parallax

1 * spectral type & luminosity class

(giant, supergiant white dwarf.

2 (apparent) M_v = 2.1 - 6.5

$M_v = m_v + 5 - 5\log d$?? d of *

(4.7 - 20.5/5 = log d, erase)

4.7 - 5 = 26.2/5 = log d. erase

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ten to minus five point two four so this one is [ke] parsec. one parsec equals one a-u so this star is sun [oke ōke] this spectroscopic parallax we can calculate distance star near star (student: I don't understand how you can have a negative parsec) negative parsec negative parsec why is negative ten to the minus two four not negative, positive ten to the power is always positive [ke] five point two four minus [ke] inverse log [ke]. [ōke] so this one is very important [ke ōke] eh next. open your book page one o three....

$$-\frac{26.5}{5} = \log d$$

$$\log d = -5.24$$

$$d = 10^{-5.24} \text{ PC}$$

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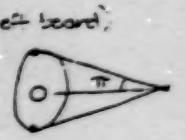
APPENDIX B: Transcription of the American's explanation of spectroscopic and trigonometric parallax and his simultaneous use of the blackboard

...the first thing we're going to do is discuss a little about distance determinations and there are two types of distance determinations we're going to talk about tonight, one is trigonometric parallax and the other is spectroscopic parallax and trigonometric parallax we've already um men-- I've already mentioned before when defining what a parsec was and if you remember um the best way to find out what happens is to hold your finger in front of your face and you close one eye and then you open and close the other eye and you'll notice if you look at the back at some object like the front board when you do that and change eyes your finger appears to shift with respect to the background [ks] now thats trigonometric parallax and the reason that is is because your baseline changes from side to side so your line of sight changes as you go further out there, um and because of that we can, if we can measure the angle our finger changes with respect to the background we can find how far away it is from our line from our observing point so if I hold my hand out here and made detailed measurements of the angle it moves in space I could tell how far away my finger is in front of my face which isn't very useful, I could care less, but um, for stars its really helpful [ks] and the only way we can do that is we need a large baseline because stars are phenomenal distances away and it turns out that the baseline of our orbit around the sun is fairly large and provides a decent baseline and if we make an observation of a star at two points in the earth's orbit at two different times a half year apart we look at a certain star from here, then it makes an angle with respect to the direct line from the sun to the earth or the sun to the star and this angle here is the angle of parallax and its given in terms of capital pi and its in arcseconds which is important to remember. now only certain stars will actually have an obeervable parallax and there are very few of 'em and so its not a very useful method its good for the closest stars 'cuz distance, the maximum distance you can really determine is about one thousand parsecs [ks] which is also one kiloparsec so anything further than one thousand parsecs away we have no idea how far away it is by trigonometric parallax. but its useful for the near stars and to find the distance, the distance is just equal to one over parallax [ks] and that will give you a distance in parsecs so that's the first way to determine the distance of the stars. trigonometric parallax. now the second method is spectroscopic parallax and that's a mathematical relation between distance and magnitude and it involves a little



1000 pc

$d = \frac{1}{\pi}$ pc.

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bit of derivation which I won't go through all of it but I'll go through a little of it to see how we got to where we got , remember perhaps the magnitude of two stars are related by this equation [ke] the difference in magnitude is equal to two point five times the log of the luminosity of the second star divided by the luminosity of the first star, so we'd like to find some way of finding the distance and it turns out there's a way of doing that. the first thing we find is a thing called absolute magnitude and the absolute magnitude of a star is given in capital "m" is defined to be the magnitude that star would have if it were ten parsecs away, from the earth and so we can change this equation and make m two equal the absolute magnitude and 1 two would be the eh the magnitude the star would have to have if it were at that distance because its absolute magnitude but this relation right here is, we can change 1 one since its the same star, this relation is totally unhelpful right now because we don't know enough about the luminosity of the stars in general so we have to get this in more (mumbled) units. we also have to know the distances so the first thing we do is, remember that luminosity is proportional to one over distance squared that means that the eh effective brightness of the star drops off as the inverse of the distance squared, which means that if I have a candle so many feet away from me and I look at it and measure how bright it is, say its twenty feet away if I move a distance twice as far away from that candle then its apparent brightness is not a half as great but a fourth as great and if I move three times as far away then its magnitude, apparent brightness is a ninth as great, so then luminosity drops off to one over d squared, so we can now substitute d back into this initial equation now by saying proportional that means its equal to a constant, over d squared and that constant is the same for any luminosity it doesn't matter which star you use so when you substitute this into this equation, the constants cancel out and you're left with, d squared over ten squared, the ten I've already put in ten parsecs for that distance the absolute magnitude because that's the way it was defined so I know the distance for the absolute magnitude is ten parsecs so I can substitute that in immediately, and so this distance here is the actual distance of the star [ke] so now we have a relationship that involves the magnitudes and the distance so we can solve this for distance and without going through needless algebra. that's the spectroscopic parallax determination for distance, and that's valid for distances from zero persecs to infinity [ke] in theory, it doesn't make any difference how far away a star is if we can see it we can determine its

(right board)

$M_1 - M_2 = 2.5 \log(\frac{L_2}{L_1})$

M

$L \propto \frac{1}{d^2}$

$L = \frac{1}{d^2} = \frac{k}{d^2}$

$\frac{d^2}{10^2}$

$d = 10^{(1 + d - M)}$

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distance, however there are two limitations on it, the first one is purely observational and that deals with the brightness of the sky itself, the sky has an apparent magnitude of plus twenty-six, that is deep space sky, and so any star that is dimmer than plus twenty-six can't be seen because we just can't see it period and so the sky would be brighter than the star and in fact the best telescope we have can only get down to about eh plus twenty-four so ay star dimmer than plus twenty-four we can't see so we can't find out how far away it is so that gives us an upper limit to refer to this distance when referring to a star. another proble is that there's a lot of dust and gas in our galaxy and the universe in general and on a short scale over a few parsecs in the solar vicinity then the dust is not significant in all directions in some directions there might be a dust cloud where its highly significant but in general it won't be significant for short distances through space, and in fact even if we go out into inner galactic space we can say there's nothing there in the density um, in space, to give you an idea the density of air is, I don't know, about one-hundredth of a gram per cubic centimeter (inaudible) the density of inner galactic space is on the order of ten to the twenty-five over ten to the minus twenty-five cubic centimeters so it's ten to the twenty-three times less dense [kg] so if you were to take well there's nothing out there essentially its its almost a vaccuum but if you were discussing distances on the order of the distances here to the galaxy even this tiny amount of dust along our line of sight adds up to an amazing amount of material and it tends to block starlight and stars behind dust clouds appear dimmer and redder to us because, one of the facts is that blue light all light is scattered by dust but the shorter the wavelength the more effectively it's scattered so when the wavelength is smaller than or equal to the size of the particles doing the scattering it's variably scattered so the space dust particles are on the order of a few microns which is ten to the minus six meters and so wavelengths that are longer than that will be largely uneffected by dust but wavelengths that are shorter will be reflected so the blue light is reflected perferentially over the red light so the starlight is redder through dust clouds its also dimmer through dust clouds a lot of it is just absorbed by the dust itself so if we're looking at a star behind a dust cloud it will appear further away than it really is because it will appear dimmer than it really is so all this dust and gas in the galaxy and universe puts another limit on our distance determination (inaudible) because it blocks out over great distances stars are blocked out by the dust and we can't see them. but its very useful to

$M_{app} = +26$

$M = +24$

$0.01\ g/cm$

10^{-23}

determine distances of some galaxies using it, and you can determine the distance of anything in our galaxy if you can see it, now the problem with dust can be accounted for if you know how much dust you're looking for if you know how much dust is along your line of sight you can calculate the resonating effect of the dust and include in that equation the two distances and it will always come out that if the star is behind dust this formula will give you a distance further away than the star actually is, so this is really an upper limit to the distance so I can really write distance is less than or equal to $d \leq$ that number [kp] if there's dust there it will always appear further away than the star is [kp] . now what can we do with that formula, I mean that's all great but we can only see a star from where we are so we only know its apparent magnitude and that's just what you observe from earth, and if we can get on a spaceship and go ten parsecs from that star and determine its magnitude then we know its absolute magnitude, the day we can do that we can just go to the star in the first place and find out how far away it is, so but eh so what we have to do is find out some way of finding out what the absolute magnitude is this is where the Hertzsprung-Russell diagram comes in so after we've gotten to this point we change tacks and start talking about spectral classes....

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